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(UTILITY PATENT)

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INVENTION TITLE: METHOD OF MANUFACTURE OF CERAMIC COMPOSITE WIRING STRUCTURES FOR SEMICONDUCTOR DEVICES

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Sir:

Your applicant(s) named above hereby petition(s) for grant of a utility patent to him (them) or any assignee(s) of record, at the time of issuance, for an invention, more particularly described in the following specification and claims, with the accompanying drawings, verified by the accompanying Declaration and entitled:

METHOD OF MANUFACTURE OF CERAMIC COMPOSITE WIRING STRUCTURES FOR SEMICONDUCTOR DEVICES

Cross Reference To Related Applications

[0001] This Application is a divisional application of U.S. Patent Application Serial No. 09/990,615, filed 21 November 2001 and entitled "Method Of Manufacture Of Ceramic Composite Wiring Structures For Semiconductor Devices", which is a divisional of U.S. Patent No. 6,323,549, filed 25 June 1999 and entitled "Ceramic Composite Wiring Structures For Semiconductor Devices And Method Of Manufacture", which is a continuation of International Application Serial No. PCT/US97/23976 filed 29 December 1997, and a continuation-in-part of U.S. Application Serial No. 09/004,928 filed 09 January 1998, now U.S. Patent No. 6,143,432, which in turn is a continuation-in-part of U.S. Patent Application Serial No. 08/697,739 filed 29 August 1996 now U.S. Patent No. 5,707,715. International Application Serial No. PCT/US97/23976 also claims priority of U.S. Provisional Application Serial No. 60/033,983 filed 30 December 1996.

Background Of The Invention

[0002] The present invention relates generally to circuit wiring boards and, more particularly, to ceramic composite circuit wiring boards and/or multichip modules and methods to construct the same.

[0003] Semiconductor integrated circuits ("SIC") or semiconductor chips are being developed to operate at increasingly higher speeds and to handle larger volumes of data. This trend has caused the density of electrical interconnections required between the semiconductor chip and the larger electronic system to increase dramatically. Conversely, this ultra-large scale integration restricts the physical dimensions of the SIC. The drive to implement more sophisticated SIC's which require much larger numbers of electrical interconnections to be

crammed into smaller physical dimensions creates a technical bottleneck, wherein SIC performance is increasingly limited by the circuit board/package connecting the chip to the larger electronic system.

[0004] The industry convention has been to use a lead frame that electrically interconnects the SIC to a printed circuit board ("PCB"), and to envelop the chip and lead frame in a ceramic laminate package. The packaged SIC is socketed to the PCB, which electrically connects the SIC to the larger electronic system. The modern, more sophisticated SIC's generate greater amounts of heat than their predecessors. This heat, if not dissipated from the SIC, reduces circuit performance. Robust lead frames have been able to function as both electrical connection and heat sink, however, as the density of leads per unit area has increased, the physical dimension of the individual lead must be shrunk. Smaller lead sizes sharply limit their function as a heat sink. This has forced system manufacturers to dissipate thermal loads through unmanageably large heat sinks attached to the SICs, which hampers the drive towards smaller, mobile platforms.

[0005] Furthermore, the operating speed of the more sophisticated SICs is increasingly limited by the printed circuit board. Conventional PCBs have routed electrical signals between system and SIC through an electrode network patterned on the PCB surface on which the semiconductor chip is mounted. To allow the SIC to operate at higher speed the interconnections between the semiconductor chip and the electronic system must be low-resistance. Lower resistance electrical contact is achieved by shortening electrode length and by decreasing electrode resistivity. Shorter electrode lengths are engineered by embedding an electrical interconnection network within the circuit board rather than one patterned on the surface. The prior art discloses methods to construct multilayer ceramic composite printed circuit boards with electrical interconnection networks embedded within the circuit boards. However, these methods are performance-limited because the embedded electrode network is composed of metallic films, conducting pastes, or both, which have much higher electrical resistance than the wire form of the same conducting metal. Lower-resistance at higher signal frequency is also enhanced by forming the wiring board from low dielectric constant materials. Therefore, circuit wiring board and

multichip module designs that comprise electrode networks of conducting metal wire embedded within a low dielectric ceramic, such as silica or alumina, and simultaneously contain heat sinks, embedded within the ceramic to dissipate heat generated by the SIC would be highly desirable.

[0006] Relevant prior art includes the following patents. Fujita et al., U.S. Patent No. 5,396,034, discloses methods to construct a thin film ceramic multilayer wiring hybrid board. Bonham et al., U.S. Patent No. 5,396,032, discloses the construction of a multi-chip module ("MCM") with two sets of lead frames, one set supplying input/output bond pads, and another independent set to provide electrical contact to test pins that can be used to isolate and examine the performance of one or multiple devices mounted on a substrate within a cavity of said MCM, wherein the device(s) is (are) wire bonded to said pads. The material comprising the MCM package body can be ceramic, plastic, laminate, or metal, but the substrate on which the devices are mounted does not contain internal electrical interconnects and/or heat sinks. Wiesa, U.S. Patent No. 5,375,039, discloses the construction of a printed circuit board with internal heat dissipation means channeling heat from power units mounted on the board to heat sinks, wherein the core of the printed circuit board comprises glass cloth. Chobot et al., U.S. Patent No. 5,363,280, discloses methods to construct a multilayer ceramic circuit board in which some metal film layers function as electrode networks, and are separated from other metal film layers which function as heat sinks. Ohtaki et al., U.S. Patent No. 5,300,163, discloses a process to fabricate a multilayer ceramic circuit board comprising a ceramic substrate, multiple layers of green tape with conductive paste patterns therein, and via holes with conductive paste to electrically interconnect the assembled layers. Cherukuri et al., U.S. Patent No. 5,256,469, discloses a multilayered co-fired ceramic-on-metal circuit board prepared using ceramic green tapes and a system of low-temperature, high expansion glass ceramics. Capp et al., U.S. Patent No. 5,113,315, discloses the construction of ceramic circuit board structures in which heat dissipation extensions are embedded in the ceramic member by laser drilling holes into the ceramic member and filling the holes with conductive metal using well-known metal deposition techniques. Plonski, U.S. Patent No. 4,679,321, discloses a method of making interconnection boards with coaxial wire interconnects on the external major surface of the board substrate that opposes the

major surface upon which integrated circuits are mounted. Ushifusa et al., U.S. Patent No. 4,598,167, discloses the construction of multilayered ceramic circuit board that comprises a plurality of integrally bonded ceramic layers, each having a patterned electrically conducting paste layer and through holes filled with electrical conductors for connecting the patterned electrically conducting layers on respective ceramic layers to form a predetermined wiring circuit. Takeuchi, U.S. Patent No. 4,551,357, discloses a manufacturing process for ceramic circuit boards that comprises firing a circuit pattern formed from an organic-laden conductive paste on the surface of a green-state ceramic with an organic binder.

[0007] It is therefore an object of the present invention to provide a composite wiring structure which enhances SIC performance.

[0008] It is another object of this invention to provide a composite circuit wiring structure which increases the allowable operating speeds of SICs.

[0009] It is a further object of this invention to reduce compressive and shear stresses within the composite structure.

[0010] It is another further object of this invention to provide a composite circuit wiring board structure wherein the structure's dielectric member is either a ceramic or an organo-ceramic composite.

[0011] It is still another object of this invention to provide a highly efficient and effective ceramic composite wiring structure for SICs and the method of manufacture thereof.

Summary of the Invention

[0012] The objects set forth above as well as further objects and advantages of the present invention are achieved by the preferred embodiments of the invention described herein.

[0013] The preferred embodiments include a composite circuit wiring structure having one or more electrodes on one major surface of a dielectric member, and wherein a semiconductor integrated circuit ("SIC") is placed in direct electrical contact with the electrodes which are electrically contacted, through an electrical interconnection network within the dielectric ceramic member, to an external input/output signal driver.

[0014] Still further the preferred embodiments provide a composite circuit wiring structure wherein the dielectric member also contains an embedded thermal distribution network.

[0015] Even further the preferred embodiments provide a composite circuit wiring structure having one or more electrodes on one major surface of a dielectric member, and wherein at least one SIC is placed on a mounting area and electrically contacted to at least one electrode through a conducting wire means.

[0016] Still further the preferred embodiments reduce thermally generated compressive or shear stresses between the circuit wiring board's dielectric member and the embedded electrical interconnection network or the embedded thermal distribution network through the use of networks with curved joints.

[0017] Even further this invention reduces thermally generated compressive or shear stresses between the circuit wiring board's dielectric member and the embedded electrical interconnection network or the embedded thermal distribution network through the application of organic resins with high thermal decomposition temperatures to the networks prior to embedding the networks in the ceramic member.

[0018] Still further the present invention permits the inclusion of blocking capacitors with the dielectric member of the composite wiring structure.

[0019] Even further still the present invention provides the above-mentioned embodiments to be constructed with a ceramic or an organo-ceramic material as the dielectric member of the composite wiring structure.

[0020] More specifically a preferred embodiment of this invention relates to a dielectric (ceramic or organo-ceramic) composite circuit wiring board having one or more electrodes on one major surface of a ceramic member and wherein a semiconductor integrated circuit ("SIC") is placed in direct electrical contact with the electrodes. The SIC is electrically contacted, through an electrical interconnection network, made up of a conductive wire, preferably of copper wire, to other SIC's electrically contacted to other electrodes on the circuit wiring board's major surface, and/or to an external input/output signal driver that is electrically contacted to the ceramic circuit wiring board. This is accomplished either through yet another electrode on the circuit wiring

board's major surface, or through a segment of conductive wire, connected to the electrical interconnection network, that protrudes through a minor surface of the circuit wiring board's dielectric member. The dielectric member also contains an embedded thermal distribution network of heat sinks, formed from elongated thermally conducting material such as metal, or hollow tubes in which a heat absorbing fluid is circulated. The embedded thermal distribution network is located in the vicinity of, but not in direct contact with, the electrodes making direct electrical contact with the SIC, and the terminal points of the embedded heat sinks protrude through a minor surface of the ceramic member to make thermal contact with a further heat sink or thermal reservoir that is external to the circuit wiring board.

[0021] As an example, the dielectric member comprises aluminate or silicate ceramic phases. Silica ceramic phases are particularly preferred to reduce the level of signal attenuation through dielectric loss mechanisms at higher signal frequencies. Another metal member is bonded to the major surface of the circuit wiring board's ceramic member that opposes the major surface on which the SIC is contacted to the electrodes. The invention also encompasses methods to construct the circuit wiring board structure through low-temperature processing methods.

[0022] The use of solution precursors allows ceramic to be formed around the network assemblies by filling the area bordered by the mold materials, mounting supports, and the base metal member with liquid precursor and driving the chemical reaction that transforms the liquid precursor into the corresponding solid state ceramic. The invention preferably incorporates therein the use of metalorganic precursors, whereby metal precursors to the ceramic oxide are first reacted with a carboxylic acid, such as 2-ethylhexanoic acid, to form a solution of carboxylic acid salts in organic acid solution. However, other solution processing techniques, such as sol-gel techniques, could also work as effectively and is considered to be within the spirit and scope of the invention.

[0023] The area filled with liquid precursor is filled with ceramic after the transforming chemical reaction is completed. As described below, the transforming chemical reaction bonds the ceramic to the network assemblies, the metal member, and the walls of the bordering mold materials and/or mounting supports. The liquid properties of the solution allow precursor

materials to uniformly envelop the network assemblies. When metalorganic precursors are used, pyrolytic action decomposes the carboxylic acid salts into their corresponding metal oxides. Unstable metal oxide radicals are formed as a result of pyrolysis, which rapidly bond to stable organic and inorganic surfaces that are part of the network assemblies, the base metal member, and the mold materials and/or mounting supports. The unstable metal oxide radicals also bond with other decomposing metal oxide radicals to form a contiguous ceramic network.

[0024] The volume fraction of solid state ceramic is less than the volume solution precursor as the decomposition (or unwanted reaction) products are removed. Thus, it is advantageous to utilize a high solid content precursor solution, which is often quite viscous; or to pyrolyze the precursor in situ as it is applied, as is the case when the precursors are spray pyrolyzed onto an already heated assembly.

[0025] The action of spray pyrolysis allows undesirable reaction by-products, such as the precursor solvent and decomposition products to be physically removed at a much faster rate than the ceramic precursors are applied and simultaneously formed into ceramic. Thus, spray pyrolysis allows a higher volume fraction of solid state ceramic to occupy the region into which it is being applied.

[0026] The present invention also permits the formation of an organo-ceramic dielectric, if such a dielectric member is desired, through the incomplete decomposition of the dissolved metalorganic ceramic precursors. The present invention forms metalorganic precursors by directly or indirectly reacting the metal precursor(s) with a carboxylic acid solvent to produce a solution of carboxylic acid salt(s) dissolved within the carboxylic acid. 2-Ethylhexanoic acid is a preferred solvent and has a flash point of 210 degrees C. 2-Ethylhexanoate precursor salts will typically begin to decompose over temperatures in the range of 225-375 degrees C, depending upon the chemistry of salt's metal. Thermal decomposition is usually complete at temperatures above 400-475 degrees C. A composite organo-ceramic dielectric can be formed by spray-pyrolyzing the solution on to the circuit wiring board assembly heated to temperatures above the initial decomposition temperature(s) of the dissolved carboxylic acid salt(s), (225-375 degrees C), yet below the temperatures at which the salt(s)'s organic ligands thoroughly decompose, (400-

475 degrees C). During spray-pyrolytic decomposition the carboxylic acid evaporates, depositing waxy carboxylic acid salts that decompose *in situ*. When the circuit wiring board assembly is heated to an appropriate temperature, the resultant dielectric material is a matrix of fully deflagrated oxide ceramic with incompletely decomposed organic material, thereby producing an organo-ceramic dielectric member.

[0027] Another embodiment of the present invention relates to a dielectric (for example, the dielectric being either a "pure" ceramic or organo-ceramic) composite circuit wiring board that comprises a metal member including one or more electrodes, and one or more mounting areas, all on one major surface of a ceramic member. At least one SIC is placed on the mounting area and electrically contacted to at least one electrode through a conducting wire means. The SIC is in further electrical contact, through an electrical interconnection network to other SIC's in electrical contact with other electrodes on the dielectric circuit wiring board's major surface, or to an external input/output signal driver that is electrically contacted to the dielectric circuit wiring board either through yet another electrode on the circuit wiring board's major surface, or through a segment of conductive wire, preferably copper wire, connected to the electrical interconnection network, that protrudes through a minor surface of the circuit wiring board's dielectric member. The dielectric member also contains an embedded thermal distribution network which includes heat sinks formed from elongated thermally conducting material such as metal, or hollow tubes in which a heat absorbing fluid is circulated. The thermal distribution network may or may not be in thermal contact with the SIC through the mounting area, and the terminal points of the embedded heat sinks protrude through a minor surface of the dielectric member to make thermal contact with a thermal reservoir that is external to the circuit wiring board. The dielectric member may be composed of aluminate or silicate ceramic phases. Another metal member is bonded to the major surface of the circuit wiring board's dielectric member that opposes the major surface on which the SIC is contacted to the mounting area and the electrodes.

[0028] Two methods are employed within the present invention to reduce the deleterious effects of stress on the dielectric member and the embedded network structures. The first deploys curves in the design of the embedded network structures to high stress points that result

from sharp edged structures. When the network structures are designed with curved, rather than sharp-cornered L-joints and T-joints the stress is more evenly distributed over the radial arcs, as opposed to building up intense compressive forces at the sharp critical points in the network. Second, compressive stress is also reduced in the network by coating the (copper) metal wire forming the electrical interconnection network and the heat pipes forming the thermal dissipation network with an organic resin.

[0029] For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description taken in conjunction with the accompanying drawings and its scope will be pointed out in the appended claims.

Brief Description of the Figures

[0030] **FIG. 1A** shows a top view of a preferred embodiment of the dielectric composite wiring structure of this invention;

[0031] **FIG. 1B** shows a front view, partially in cross section, of the preferred embodiment of the invention shown in **FIG. 1A**;

[0032] **FIG. 2A** shows a top view of another preferred embodiment of the dielectric composite wiring structure of this invention;

[0033] **FIG. 2B** shows a front view, partially in cross section, of the preferred embodiment of the invention shown in **FIG. 2A**;

[0034] **FIGS. 3A** (exploded fashion), **3B** and **3C** show the details of the assembly methods used to construct the dielectric composite wiring structure of this invention;

[0035] **FIGS. 3D** (exploded fashion), **3E** and **3F** show further details of the assembly methods used to construct the dielectric composite wiring structure of this invention;

[0036] **FIG. 4A** shows a top view of a further embodiment of the dielectric composite wiring structure of this invention;

[0037] **FIG. 4B** shows a cross sectional side view of the embodiment of the invention taken along line IV-IV of **FIG. 4A** with thermal distribution network omitted for clarity; and

[0038] **FIGS. 5A** and **5B** show, in pictorial fashion, portions of curved network members, embedded within the dielectric, utilized with the dielectric composite wiring structure of this invention.

Detailed Description of Preferred Embodiments

[0039] Reference is now made to **FIGS. 1A**, **1B**, **2A** and **2B** which illustrate the preferred embodiments of the composite structure **10** and **10'** of this invention, also referred to as a composite wiring structure, while **FIGS. 3A-3F** illustrate the sequential steps used to create the composite structure with an electrical network, interconnects and heat sinks internal to the composite's dielectric member. For ease of understanding of this invention, like reference numerals will be used throughout the following description to identify identical elements illustrated in all embodiments.

[0040] The composite circuit wiring structure **10**, although not limited thereto, is primarily used as a circuit wiring board, or, alternatively, as a multichip module. In the preferred embodiment of the invention shown in **FIGS. 1A** and **1B**, the composite structure **10** has a top conductive, preferably metal member **12** with an exterior major surface **14** upon which at least one SIC **16** eventually will be mounted. Any suitable series of conductive members **18** form an electrical contact between the top metal member **12** and the integrated circuits of the SIC **16**. With the preferred embodiment of the invention shown in **FIGS. 1A** and **1B**, the top metal member **12** functions as an electrode contact. The composite structure **10** of this invention further includes a ceramic or an organo-ceramic dielectric member **20** bonded preferably by a covalent bond to the interior major surface **22** of the top metal member electrode **12**, and an electrical interconnection network **24**. The electrical interconnection network **24** is made up of at least one conductive wire, preferably metal such as copper, embedded within the ceramic or organo-ceramic member **20** (also referred as dielectric member **20**). The copper wire is bonded at one end to the interior major surface **22** of the top metal member electrode **12** in at least one location, that is, where the top metal member makes electrical contact to the SIC **16**. The at least one wire forming the electrical interconnection network **24** may optionally also have a wire

termination **24A** that protrudes through an exterior minor surface of the dielectric member **20** to form an electrical contact, through the electrical interconnection network **24**, between a top metal member electrode **12** and at least one input/output signal driver **25** that is external to the circuit wiring board. A further embodiment of the present invention illustrative of the use of a mounting support utilized with the interconnection network **24** is described in detail with respect to Figures **4A** and **4B**. Electrical contact between the SIC **16** and an external signal input/output driver may alternatively be made between two top metal member electrodes that are linked through the metal, preferably copper, wire of electrical interconnection network **24**.

[0041] The composite wiring structure **10** of this invention further includes a thermal distribution network **26** embedded within the dielectric member **20** and electrically insulated or isolated from the electrical interconnection network **24** . The thermal distribution network **26** includes at least one heat sink that is located in the vicinity of, but is not in contact with, the interior major surface **22** of the top metal member **12** at a location where the top metal member **12** makes electrical contact with the SIC. The heat sinks **28** forming the thermal distribution network **26** may be composed of elongated thermally conducting material, for instance, a high thermal conductivity metal such as copper, or the heat sinks may be alternatively composed of hollow tubes through which a thermally absorbing fluid is circulated. The heat sinks **28** forming the thermal distribution network **26** protrude through at least one exterior minor surface of the ceramic or organo-ceramic dielectric member **20** and are placed in thermal contact with a thermal reservoir(s) **30**.

[0042] The thermal reservoir **30** may be simultaneously used as or connected to a mechanical fixture that secures the circuit wiring board to an electrical ground, or both. Both preferred embodiments of composite wiring structure **10** and **10'** of this invention also comprise a bottom metal member **32** bonded to the opposing major surface of the dielectric member **20**.

[0043] The dielectric member **20** may be composed of an aluminate (Al_2O_3) or silicate (SiO_2) based ceramic or organo-ceramic composite. The composite wiring structure **10** of the invention may be configured to electrically connect a single SIC to one or multiple external signal

input/output drivers, or configured to interconnect multiple SICs mounted on the top metal member to each other as well as to one or multiple external input/output signal drivers.

[0044] Another preferred embodiment of the invention is shown in **FIGS. 2A** and **2B** wherein the composite wiring structure **10'** has the top metal member **12** segmented into electrode areas **34** and at least one mounting area **36**. In this embodiment of the invention the electrical interconnection network **24** is embedded within the dielectric member **20** and connects, through at least one conductive wire, preferably metal such as copper, the electrode areas **34** of the top metal member **12** to an external signal input/output driver. The SIC **16**, bonded to a mounting area **36** of the top metal member **12**, is electrically connected to at least one electrode area **34** by means of a wire conductor **38**. The electrical interconnection network **24** may electrically connect the SIC **16** to the external signal input/output driver through at least one metal wire that protrudes through a minor surface of the dielectric member **20**, or through another free electrode area **34** that is part of the top metal member **12**. In addition, in this embodiment of the invention, at least one heat sink **28** of the thermal distribution network **26** may, optionally, directly connect a mounting area **36** of the top metal member **12** to a thermal reservoir **30** (as shown at **40**) external to the circuit wiring board through a heat sink protruding through a minor surface of the dielectric member **20**. A bottom metal member **32** is bonded to the exterior major surface of the dielectric member **20** that opposes the major surface that is bonded to the top metal member **12**.

[0045] Reference is now made to **FIGS. 3A-F** for a detailed explanation of the methods to reduce the above referenced ceramic composite wiring structures **10** and **10'** to practice. As shown in **FIG. 3A** the top metal member **12**, preferably a copper sheet 0.5 mm to 3 mm in thickness, is used initially as a substrate upon which the electrical interconnection network **24**, thermal distribution network **26** and dielectric member **20** will be formed. Opposing areas are designated on both the exterior major surface **14** and the interior major surface **22** as electrode areas **34**, and, if designs as depicted in the embodiment of **FIGS. 2A** and **2A** are produced, as mounting areas **36**. The remaining area(s) **42** that are not part of the designated areas **44** on the top metal member **12**, may be selectively scribed, etched, or pressed to have lesser thickness than

the designated areas on the major surface of the top metal member **12** that will become the exterior major surface **14** prior to using the copper sheet or metal member **12** as a substrate. It is preferred practice, during construction, to orient the exterior major surface **14** face down (that is, **FIGS. 3A-F** would actually be viewed upside down) and to place mounting supports **46** which may be removed over the interior major surface in those regions of the remaining area(s) **42** that will not functionally serve as a part of the circuit wiring board.

[0046] The mounting supports **46** (preferably being removable) may be made of a solid material that has bore holes of appropriate diameter to secure terminal points of those segments of heat sink **28** used to form the thermal distribution network **26** or even, in some cases, the wires of the electrical network **24**. A mounting support **54** as shown in **Figs**, **4A** and **4B**, optionally removable, may be utilized in conjunction with the metal wire used to form the electrical interconnection network **24** that protrude from the minor surface(s) of the dielectric member **20**. The actual details of the mounting support **54** is described in detail with respect to Figures **4A** and **4B**.

[0047] Alternatively, the removable mounting supports **46** may be a form of plastic material that solidifies or gels into a solid or semi-solid mold after the segments of heat sink **28** and/or metal wire (preferably made of copper or other theramlly conductive material) are embedded in it, or it may take the form of a combination of solid material and plastic material. A wide variety of plastic, glass, ceramic, or metallic materials may usefully serve as the removable mounting supports **46,** provided the selected materials do not form a permanent bond with the copper substrate, retain their solid or semi-solid molded form at process temperatures ranging between 225-475 degrees C, and can be easily removed, preferably by soluble means that does not erode the dielectric member **20**, metal members **12** and **32**, and the network members **24** and **26**. Recommended removable mold materials include a plastic composite comprising polyvinyl formal, or polyvinyl butyral, loaded with hollow silica and a high temperature organic adhesive. Suitable high temperature adhesives include, but may not be limited to, aromatic heterocyclic polymers, such as benzimidazole polymers, or ethynyl-terminated polyimides with small additions of hydroquinone to retard thermal reactions of the ethynyl groups, or arylene-ethers,

commercially available as Polymer 360 or Astrel 360. The removable mold materials are typically formed at temperatures ranging between 350 degrees C and 470 degrees C under pressures of 50 psi to 2000 psi, and should be made to withstand the ceramic processing temperatures (225 degrees C to 475 degrees C), be resistant to the etchants used to remove the remaining areas **42** of the metal members **12** and **32**, and yet be sensitive to dispersal in a solvent that is inert to the dielectric member **20**, metal members **12** and **32**, and the materials that comprise the electrical interconnection network **24** and the thermal dissipation network **26**.

[0048] It is essential to the proper functioning of the circuit wiring board that the electrical interconnection network **24** and thermal dissipation network **26** are electrically insulated or isolated from one another in the finished body. Therefore, all portions of the electrical interconnection network **24** must not physically contact any portion of the thermal dissipation network **26**, and vice-versus, prior to and after the application of the dielectric member **20**. It is also imperative that an intertwining electrical interconnection network **24** and thermal dissipation network **26** are physically organized such that the distances separating the two are sufficient to ensure electrical isolation over anticipated voltages after the dielectric member **20** is inserted between them. Ideally, the thermal dissipation network **26** should be connected to an electrical ground.

[0049] Manufacturing efficiency can be increased if some of the mounting supports **46** also comprise, in part, removable material **48** that will not form part of the final circuit board, and the thermal heat reservoirs **30** to which the thermal distribution network **26** will be connected via the heat sinks **28** embedded in the dielectric member **20** that protrude through a minor surface of the dielectric member **20**. The heat sink/mounting supports can only be positioned in the remaining areas **42** that are adjacent to the minor surfaces of the dielectric member **20** through which only heat sinks **28** connected to the thermal distribution network will protrude.

[0050] Those segments **50** of the copper wire used to form the electrical interconnection network **24** and those segments of heat sinks **28** used to form the thermal distribution network **26** that will protrude from the dielectric member **20** once the circuit wiring board is completed are embedded into the mounting supports **46**. When a thermal reservoir **30** is incorporated as part of

the mounting support **46**, those segments of heat sinks that will protrude from the minor surface(s) of the dielectric member **20** are attached through the material **48** of the mounting support to the thermal reservoir **30**. The mounting supports **46** with embedded segments of copper wire and heat sinks are then positioned on those regions of remaining areas **42** on the interior surface **22** of the top metal member **12** that will not functionally serve as part of the composite wiring board as shown in **FIG. 3B**.

[0051] As illustrated in **FIG. 3B**, terminal points of the metal wire that form the electrical interconnection network **24** are then bonded to the interior surface **22** of the metal sheet at those substrate areas designated as electrode areas **34** as described with reference to **FIG. 2A**. Bonding the metal wire to the metal sheet can be achieved using a variety of brazing materials well-known to practitioners skilled in the art, electro-welding, arc-welding, or ultrasonic bonding. It is recommended to select a bonding technique that is appropriate to the electrical properties expected from the finished circuit wiring board. A preferred method of the invention is to use a bonding technique such as arc-welding to form a metal bond between the electrical interconnection network **24** and the designated electrode areas **34** of the copper metal sheet, although other conventional techniques may also be utilized.

[0052] The electrical interconnection network **24** is formed by bending a bonded metal wire and electrically contacting it to another metal wire, or a plurality of such metal wires, so constructed in a manner that is consistent with the circuit wiring pattern specified for the SIC(s) and the external input/output signal drivers. Although arc-welding is the recommended means by which to form electrical interconnections between metal, preferably copper, wires so constructed, other conventional techniques may be also utilized. The invention may be used to construct a blind via by electing not to bond a copper wire so constructed with any other copper wires and terminating the blind via metal wire at another electrode area, or by terminating the blind via metal wire in a removable mounting support. A pre-constructed wire lattice used to form the electrical interconnection network **24** that is press-fit at its terminal points into inserts **52** drilled into the electrode areas **34** of the copper sheet substrate may alternatively be constructed, for instance, from a vacuum cast. This method of preparing the electrical interconnection network is depicted

in **FIG. 3B** for convenience. When it is intended to produce a circuit wiring board that comprises electrode areas and mounting areas, according to the preferred embodiment depicted in **FIGS. 2A** and **B**, contact sections of heat sinks **28** comprising the thermal distribution network **26** may be bonded to the mounting areas **36** using the methods described above for contacting terminal points of the electrical interconnection network **24** to the electrode areas **34**.

[0053] As pointed out above, mounting supports **46**, may optionally be removed after the circuit wiring board "CWB" is fully assembled. The mounting support may, alternatively, remain as a permanent fixture in the finished CWB as a component. As shown in **FIGS. 4A** and **4B** mounting support **54**, electrically connects the conducting wire(s) **50** forming the electrical interconnection network **24** to input/output signal drivers (not shown) that are external to the CWB. An illustration of a completed form of this embodiment, inclusive of the electrically connecting permanent mounting support, is shown in Figures **4A** and **4B**.

[0054] Once the electrical interconnection network **24** and the thermal distribution network **26** have been fixed to the metal substrate as shown in **FIG. 3B**, the dielectric material **20A** forming dielectric member **20** is applied as shown in **FIG. 3C** to the metal substrate and the network constructions by solution processing using methods that form a direct covalent bond between the metal members and the ceramic or organo-ceramic composite dielectric. Ceramic precursors can be dissolved in solution using techniques such as sol-gel, and/or metalorganic decomposition ("MOD"). The previously mentioned sol-gel techniques utilize metal alkoxide precursors to polymerize an inorganic ceramic network through alcohol condensation reactions. A fairly viscous precursor solution may be applied to the metal substrate and network constructions by pouring, spraying, spray-pyrolyzing, or screen-printing the precursor preparation into wells defined by the removable mounting supports **46**. The precursor solution is then reacted or decomposed in an oxidizing atmosphere to form the desired ceramic phase by heating the metalorganic precursors to temperatures above their decomposition points, (i.e., preferably 225-475 degrees C), in the case of MOD-prepared ceramic, or by heating to accelerate polymerization and alcohol evaporation from sol-gel derived ceramic.

[0055] Alumina, with a relative dielectric permittivity of **10**, and silica with a relative dielectric permittivity of 3.8, are preferred ceramic phases because of their ability to limit dielectric loss, thereby allowing electronic signals, in the case of a pure silica ceramic member, at frequencies as high as 1.2-1.5 GHz to be propagated through the electrical interconnection network **24**.

[0056] Ceramic precursors may be reapplied and the reaction/decomposition process repeated, using increasingly lower viscosity solution preparations, to fill voids in the dielectric (ceramic) **20A** that may exist after the ceramic member is initially formed. Such voids may alternatively be filled by infiltrating or impregnating the ceramic member with a low-dielectric or stress relieving organic preparation, such as, polyvinyl formal, to form an organo-ceramic composite dielectric. Polyvinyl formal has a dielectric constant of 3, a dissipation factor of 0.02 and a dielectric strength (1/8 thickness) equal to 300 Volts/mm. Poylvinyl butyral, which has a dielectric constant of 2.6 and a dissipation factor of 0.027 is another suitable impregnant. The use of carboxylic acid salt precursors and the MOD process is a preferred embodiment of this invention. Alumina 2-ethylhexanoate is a preferred metalorganic precursor for alumina ceramic members, and silicon 2-ethylhexanoate is the preferred metalorganic precursor for silica ceramic members.

[0057] Organo-ceramic composite dielectric materials may alternatively be formed by spray-pyrolyzing the solution on to the circuit wiring board assembly heated to temperatures above the initial decomposition temperature(s) of the dissolved carboxylic acid salt(s), (225-375 degrees C), yet below the temperatures at which the salt(s)'s organic ligands thoroughly decompose, (400-475 degrees C). During spray-pyrolytic decomposition the carboxylic acid evaporates, depositing waxy carboxylic acid salts that decompose *in situ*. When the circuit wiring board assembly is heated to an appropriate temperature, the resultant dielectric material is a matrix of fully deflagrated oxide ceramic with incompletely decomposed organic material, thereby producing an organo-ceramic dielectric member. This organo-ceramic composite material can be maintained if the deposited dielectric and circuit wiring assembly is not exposed to temperatures above 400 degrees C, which would cause the organic fraction to rapidly decompose. The organic

content in these spray-pyrolyzed organo-ceramic composite dielectrics can be increased by adding low-volatility resins, such as polyvinyl butyral, and/or high temperature adhesives that compatible with polyvinyl butyral to the carboxylic acid salt ("MOD") solution. Polyvinyl butyral typically decomposes at temperatures above 450 degrees C, and, thus, sticks to the matrix of partially decomposed carboxylic acid salts deposited via spray-pyrolysis at temperatures between 225-375 degrees C.

[0058] Once the dielectric material **20A** has been formed to completely envelop the electrical interconnection network **24** and the thermal distribution network **26** embedded within, its top surface is rough ground to prepare a microscopically coarse surface, i.e., with a median surface roughness that is greater than 35 microns. As shown in **FIG. 3D**, the major surface of the ceramic face of a similarly prepared metal-ceramic composite comprising the bottom metal member **32** and a dielectric member **20B**, that may not necessarily have any electrical interconnection and thermal distribution networks internal to its body, is bonded to dielectric member **20A**. This is accomplished through means of a low melting-temperature oxide glass **66** (such as a silica-borate, silica-phosphate, or alumina-silica-phosphate or alumino-silica-borate phase) or polymer adhesive. The low-melting temperature bonding agent is applied to either or both major surfaces of dielectric members **20A** and **20B** at a temperature above the softening point of the glass phase, pressing the two composites together, dielectric-face to dielectric-face, and cooling the pressed body below the softening point of the glass. The two dielectric members **20A** and **20B** may alternatively be adhered to one another using a suitable polymer instead of the low melting temperature glass. Should an organic adhesive be used to bond the composite, it must be resistant to the solvent used to disperse the removable material **48** of the removable portion of the mounting supports **46**. Therefore, it is recommended to use cross-linked ethynyl-terminated polyarylene ethers, which have demonstrated impressive adhesive properties at elevated temperatures and the ability to resist solvents.

[0059] Once the full composite has been formed as shown in **FIG. 3E**, the remaining areas **42** that will not form part of the finished wiring board are removed by etching those thinned portions of the top metal member **12** and the bottom metal member **32**. The partially completed

composite needs to be designed and structured to expose the removable material **48** of the mounting support(s) **46** once remaining areas of the top metal member **12** and the bottom metal member **32**, respectively, have been dispersed. The removable material portions **48** of the mounting support(s) **46** are then dispersed to produce the completed composite circuit wiring board with internal copper wire electrical interconnection and thermal distribution networks as shown in **FIG. 3E**.

[0060] In a further embodiment of the invention, at least one internal blocking capacitor, preferably a solid state or ceramic capacitor (designated individually as capacitors **60A** and **60B**), connect at least one conducting wire **50** in the electrical interconnection network **24** to an electrical ground. The capacitance(s) of the internal blocking capacitor(s) **60A** and B are selected so as to reduce any unwanted parasitic electrical signal(s) (noise) and improve the signal-to-noise ratio of an electrical signal traveling through the electrical interconnection network **24** between the SIC and any input/out signal drivers (not shown) external to the CWB. The incorporation of the internal blocking capacitor(s) is illustrated in Figure **4B**, in which the metal member **32** that opposes the metal member **12** upon which the SIC is placed is configured to function as electrical ground.

[0061] The internal blocking capacitor(s) **60A** may be embedded within the dielectric member **20** by fixing the internal blocking capacitor **60A** on the metal member **32** prior to applying that portion of the dielectric member **20** that will envelop the internal blocking capacitor **60A**. The capacitor **60A** may be electrically connected to at least one conducting wire **50** in the electrical interconnection network **24** by creating a hole or via **62** in the dielectric member **20** located above the internal blocking capacitor **60A** and filling the hole or via **62** with an electrically conducting substance **64**, such as a solder or a metal paste, that is also placed in electrical contact with the at least one conducting wire **50**.

[0062] It is possible with the present invention to house the internal blocking capacitor **60B** within mounting support **54** that remains as a permanent fixture of the CWB. As with capacitor **60A** a hole or via **62** with an electrically conducting substance **64** is also placed in electrical contact with the at least one conducting wire **50**. The capacitor **60B** is used to

electrically connect the SIC to input/output signal drivers external to CWB through the electrical interconnection network **24**. This preferred embodiment of the invention is also depicted in Figure **4B**. An example of the blocking capacitors that can be used with the present invention could be, but is not limited to, ceramic capacitors, preferably, multilayer ceramic capacitors.

[0063] A fundamental problem with incorporating metal wire or pipe networks within a dielectric member relates to the large mismatch(es) in the coefficients of thermal expansion between the metal and ceramic dielectric compositions, and the internal stresses, fracturing, or deformation that are generated when the composite body is thermally cycled. This problem is particularly acute when copper, which has a coefficient of thermal expansion of 16.5×10^{-6} degrees C^{-1}, is embedded in pure silica, with a coefficient of thermal expansion of 0.5×10^{-6} degrees C^{-1}. The mismatch between alumina ceramic, which has a coefficient of thermal expansion equal to 8.8×10^{-6} degrees C^{-1}, and copper is less severe, but less problematic. Heat generated by the SIC 16 is dissipated into the circuit wiring board. As the thermal distribution network **26** transfers this heat to the heat sinks exterior to the circuit wiring board it will heat, expand and compress the dielectric member.

[0064] Two methods are employed within the present invention to reduce the deleterious effects of stress on the ceramic member and the embedded network structures. The first deploys curves in the design of the embedded network structures to high stress points that result from sharp edged structures. When the network structures are designed with curved, rather than sharp-cornered L-joints and T-joints as shown in **FIGS. 5A** and **5B**, the stress is more evenly distributed over the radial arcs, as opposed to building up intense compressive forces at the sharp critical points in the network. Optimal radii of curvature for the network joints, and even the specific cross-sectional shapes of the copper wires or heat sinks used to form these networks is depended upon the thermal load imposed by the SIC and can be derived by any practitioner skilled in the art of computer simulation methods, such as the finite element method. Second, compressive stress is also reduced in the network by coating the (copper) metal wire forming the electrical interconnection network **24** and the heat pipes **28** forming the thermal dissipation network **26** with an organic resin **56** as shown in **FIG. 3A**, such as a polyvinyl formal which

decomposes at temperatures greater than **430** degrees C, comprising, in-part, a high-temperature adhesive. The resin can be applied by dip-coating a pre-constructed network into a resin bath prior to fixing it to the top metal member **12** and/or the mounting support **46**. It is preferred within the present invention to have the organic resin applied using the "pultrusion" method, whereby the metal wire member is drawn through a coating die that applies the resin as it is assembled into the electrical interconnection network **24** on the surface of the metal sheet substrate. The high decomposition temperature of the resin allows the resin to occupy space in the immediate vicinity of the network member. The ceramic member is formed and hardened to the surface of the organic resin at temperatures below the resin's decomposition temperature. The "soft" organic resin may be left in tact to act as a buffer that accommodates unequal lateral displacements between the metal network member and the ceramic member.

[0065] The applied resin compound needs to be resistant to the solvent(s) used to disperse the removable material **48** in the mounting support(s) **46** if it is to remain an integral part of the composite. Alternatively, the resin can be removed by heating the composite in an oxidizing atmosphere to temperatures in excess of its thermal decomposition temperature, or by dissolving it in a suitable dispersant. Once the resin is removed, a void space is created between the hardened ceramic member and the metal wire and/or heat sinks. This void space allows the network member to slip relative to the surrounding dielectric member when the metal network member expands or contracts to a larger degree than the surrounding dielectric member. The depth of the void space, and, hence, the thickness of the organic resin coating, is determined by the relative degree of play that would be required between the metal network member and the surrounding dielectric during maximal operational cycles for a given SIC.

[0066] Although this invention has been described with respect to various embodiments, it should be realized this invention is also capable of a wide variety of further and other embodiments within the spirit and scope of the appended claims.

[0067] We claim: